

VDM Metals

A company of ACERINOX

Alloys for the
**Automotive
Industry**



Materials for the future.

Tough demands are our business

Founded in 1930, VDM Metals developed into a world market leader for high-performing metallic materials covering the widest product and service portfolio in the industry. The quality of our products and services bases on our integrated production chain in Germany and the United States and a sales network that spans the globe serving the most demanding industries and backed by a strong R&D and Application Engineering force.

VDM Metals produces high-performance alloys for the use in extreme conditions. Our materials are made to last, resisting heavy mechanical and thermal stresses and corrosive environments, sometimes all three simultaneously. In many key technologies high-performance alloys from VDM Metals are indispensable for the industrial-scale implementation and safe control of essential processes in hot or corrosive environments.

Our nickel alloys as well as our high-alloyed special stainless steels are made from a wide spectrum of elements from the periodic table, because the solutions we develop are just as wide-ranging as the demands for which they are required.

Materials are delivered as strip, wire, rod and bar, plate and sheet, forgings or welding consumables. Our processing plants and machinery are tailored to specific production requirements and local conditions and equipped with state-of-the-art process data acquisition systems, ensuring high productivity and production reliability. Our integrated manufacturing chain means that all major production steps are in our own hands – a vital prerequisite for a robust and stable manufacturing process. The result of our efforts: maximum purity, homogeneity, reproducibility and optimum

further processing characteristics of our products. Thus, our offering is nothing less than premium materials in any form needed as well as first class services, available anywhere in the world, specially tailored logistic solutions to the needs of automotive production.

Focus on Safety and Reliability

Safety, reliability and longevity are the cornerstones of all automotive projects. It does not matter whether you are working in the area of conventional engine construction or e-mobility design, from fuel injection to exhaust systems, or in the construction of steering mechanism or airbag functionalities: VDM Metals is your ideal partner for demanding material concepts.

We perform extensive tests according to the respective customer specifications which demand for mechanical properties, corrosion and high-temperature characteristics as well as soundness and longevity of each single product. Thus, we are contributing to the realization and construction of the ever progressing automotive industry. In addition to our wide range of products we improve existing alloys or develop new materials together with our customers for special demands – an argument hard to beat.



High-quality materials for tomorrow's mobility

The challenge of mobility

Hardly any other technological development has changed everyday lives more than the automobile. Mobility forms the basis of our modern lifestyle and economic activity – it is the factor with the greatest influence on how we live within a globalized world. The issues of climate protection, environmental friendliness and resource saving are the key driving force for technological development in the automotive industry. The increasing need for mobility – coupled with a shortage of resources and ever stricter requirements for environmental protection at the same time – poses one of the greatest challenges worldwide. While reducing the consumption of fossil fuels was the most important item on the agenda a few years ago, nowadays the target of decreasing environmentally harmful greenhouse gases takes top priority. The stricter specifications and legal regulations in regard to environmental protection as well as the ever greater requirements for efficiency and sustainability both during production as well as in the automobiles themselves need to be satisfied here. Both are the object of international statutory regulations in order to cover the insatiable demand for mobility in the world while protecting resources at the same time.

Materials development for resource-friendly technology

A long service life along with the functionality of the materials used play a major role. VDM Metals offers diverse solutions with its sustainable materials. Our customers expect materials that are tailored to their individual technical needs and which

fulfill the requirements for sustainable production along the entire value added chain. We take pioneering approaches to boost the performance of our products and incorporate these in new applications. We help our customers to achieve their development goals by developing new materials.

VDM focuses on the task of reducing fuel consumption and the emission of environmentally polluting nitrogen oxides – while taking the increasing expectations for comfort and driving performance as well as safety into account at the same time. This means that smaller engines need to attain higher outputs, which leads to ever higher temperatures in the engine area. Exhaust temperatures above 1,000 °C (1,832 °F) are no rarity. The properties for the materials to be used there are tremendously diverse. Besides high-temperature strength and corrosion resistance, the mechanical load-bearing capacity plays an important role here. Wet corrosion can also be a further challenge. VDM Metals offers material solutions whose properties ensure that they are far superior to conventional stainless steels.

E-Mobility

Electric cars are the up-and-coming trend when it comes to future mobility. Alternative drive forms are the basis for this and call for completely new solutions. Here too VDM Metals provides diverse opportunities with its materials for the large-scale implementation of pioneering developments in the area of resource-saving and alternative drives.

Strong materials ...

In today's automotive industry the trend is towards ever more powerful engines with smaller engine displacement. It is the stated goal of downsizing to reduce fuel consumption while lowering the emission of pollutants at the same time. The design of these usually turbocharged engines results in higher exhaust temperatures, which entails greater requirements for the design of the components and the materials used. As a result, the service life of the engines depends on both the design as well as the materials used. Here VDM Metals has recourse to a wide variety of materials that fulfill the diverse requirements within different sections in the automobile. These include e.g. high temperatures, creep resistance, load alternation, corrosion resistance or wear resistance.

1

Fuel injection systems

The fuel systems in modern engines are designed for as low fuel consumption as possible combined with improved emission values. As an injector for instance, the Piezo injection nozzle ensures optimal injection for lower fuel consumption. As the material has specified expansion properties, VDM® Alloy 36 is used for the housing construction of the ceramic Piezo stick.

2

Spark plugs and glow plugs

Spark plugs play an important role in gasoline engines, as they are responsible for ignition of the fuel-air mixture. In this way, they influence not only the engine's performance and smooth running, but also the pollutant emission and fuel consumption. Besides a good high-temperature corrosion resistance, good spark erosion resistance is also called for.

Nearly all spark plug manufacturers use materials made by VDM Metals for their electrodes. These are available as round and flat wires e.g. made from VDM® NiCr2Mn or from VDM® Alloy 600 L. So-called long life plugs prolong the service intervals as their electrodes are alloyed with elements such as yttrium and hafnium.

Glow plugs are required in diesel engines in order to ensure that the engine starts reliably and runs quietly with low emissions in the warm-up phase.

Strips of such materials as VDM® Alloy 601 and VDM Alloy 602 CA® have proven effective for manufacturing of glow plugs.

3

Valves

Hardenable, high-temperature resistant alloys such as VDM® Alloy 80 A and VDM® Alloy 751 are used for outlet valves subject to high loads.

When it comes to commercial vehicles and passenger car diesel engines, VDM Metals has developed the alloy VDM Alloy 788 A® specially for the requirements predominant here. Besides tremendous mechanical properties, this material exhibits a better wear resistance in comparison to VDM® Alloy 80 A. Thanks to the new material, there is no need of hardfacing the valves.

4

Manifold

The manifold is the front element in the exhaust system. Besides conventional cast manifolds, manifolds made from sheet metal are increasingly being used. Dual-walled manifolds with air gap insulation ensure that the catalytic system quickly reaches its operating temperature. In this way, they help to reduce the emission of pollutants and save the environment.

Thanks to its resistance at high temperatures, VDM® Alloy 601 is a material used frequently for the manufacture of manifolds. With VDM® Alloy 40 B, VDM Metals offers an alternative material that closes the gap between special stainless steels and conventional nickel alloys. In direct comparison with VDM® Alloy 601, it is characterized by better oxidation resistance with significantly lower nickel content at comparable mechanical values.

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High-temperature sensors

High-temperature sensors are indispensable in various areas of the engine in modern vehicles. They measure the temperatures in order to protect components from damage due to overheating. That means the use of heat-resistant materials is absolutely essential for manufacturers. VDM Metals accompanies manufacturers for new developments in which metallic materials have not been used so far. VDM® Alloy 602 MCA is a customized material that can be used even at high temperatures up to 1,200 °C (2,192 °F),

having been optimized in respect to workability. This material typically allows deep-drawn sensor tips to be realized in production and installation, which are then used in sensors upstream of the turbocharging – a particularly hot area.

6

Turbocharger

The turbocharger plays a central role in downsizing and hence reducing fuel consumption plus emission rates at a simultaneously high engine output. Especially high-quality materials are used for the turbocharger design, in order to ensure a long service life and reliable functioning by the component.

Heat shield

The heat shield separates the turbine area (hot) from the compressor area (cold) in the turbocharger. Heat-resistant alloys such as VDM® Alloy 800 H and VDM® Alloy 601 are used as materials for this. If the heat shield is to exhibit elastic properties additionally at high temperatures hardenable super alloys such as VDM® Alloy 718 or VDM® Alloy C-263 are used.

Turbocharger gaskets

Hardenable super alloys such as VDM® Alloy 718 or VDM® Alloy C-263 are also used for the manufacture of turbocharger gaskets.

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Decoupling elements

Decoupling elements or flexible tubes are installed to dampen vibrations in the exhaust system. These elements reduce resultant vibrations in the engine area and compensate heat expansion. They also extend the service life of the exhaust system. VDM® Alloy 625 is highly recommended as a material thanks to its high-temperature resistance, its thermal stability and its resistance to wet corrosion (high load due to road salt in winter).

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Lambda sensor

The lambda sensor serves to control exhaust gas in gasoline, diesel and gas engines. The lambda sensor represents an oxygen concentration sensor for measuring the residual oxygen content in exhaust gas for the mixture composition. In this way, the injection volume is prepared for an optimal composition of the fuel-air mixture in order to ensure the most efficient exhaust gas treatment by the catalytic system.

VDM® Alloy 601 is used for highly stressed protective tube, while VDM® Alloy 625 or VDM® Alloy 718 is used for contact springs.

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Catalytic converter systems

The exhaust catalytic system has the task of converting harmful exhaust constituents that result while the engine is operating into harmless gases. The catalytic system is located as close as possible to the manifold in order to reach its operating temperature and hence lower pollutant emissions also in the engine's start phase. This calls for highly heat-resistant materials so as to ensure fault-free functioning over a long service life. The inside of a catalytic converter must have the maximum possible surface area for the catalyst to be used in many cells and channels for effective cleaning of the exhaust gases. Besides ceramic catalyst carriers, metallic carriers are also used.

Compared with ceramic, thin metallic foils offer many advantages in the start phase of the catalytic system owing to their low thermal capacity, thereby allowing the catalytic system to reach its operating temperature faster.

With its VDM® Aluchrom Y Hf and VDM® Aluchrom 4 18 Y Hf, VDM Metals, provides materials that can be manufactured as wafer-thin foils with a thickness of 0.001 in (0.03 mm).

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End pipes for exhaust systems

Exhaust end pipes are the visible part of every exhaust system and primarily need to have a perfect appearance that shows no sign of corrosion. These end pipes must be resistant to corrosion, as they are permanently exposed to aggressive media such as salt or rain-water during road use. Materials with high molybdenum content from VDM Metals offer advantages here compared to standard stainless steels.

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Steering**Steering torque sensors**

Optimal steering assistance is logged and set via steering torque sensors in modern steering systems. Besides a magnetic ring and the Hall sensor, two flux collectors that can be twisted against one another form the core of these systems. These are made of the soft magnetic material VDM® MAG 50. The interaction of sensors and hydraulic auxiliary systems means that optimum assistance is provided by the servo unit at all times.

Angle sensors

High-precision angle sensors (resolver) are typically used in servo motors. They can detect rotational movements and are therefore used for the positioning or speed control in electric motors. If the sensors operate at 10 kHz, ordinary electrical sheets are usually no longer adequate.

Soft magnetic materials such as VDM® MAG 50 or VDM® MAG 7904 are used here.

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Airbag

Developments over the past decades have made driving increasingly safe. Thus, seat belt tensioners and the installation of airbags has led to greater safety for the occupants in the potential

event of an accident. Complex technology is also involved here. Rupture disks contribute to safety in airbag systems. Thanks to its definite mechanical properties at elevated temperatures, VDM® Alloy 625 prevents airbags from triggering inadvertently, for example in case of vehicle fires.

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E-Mobility shielding

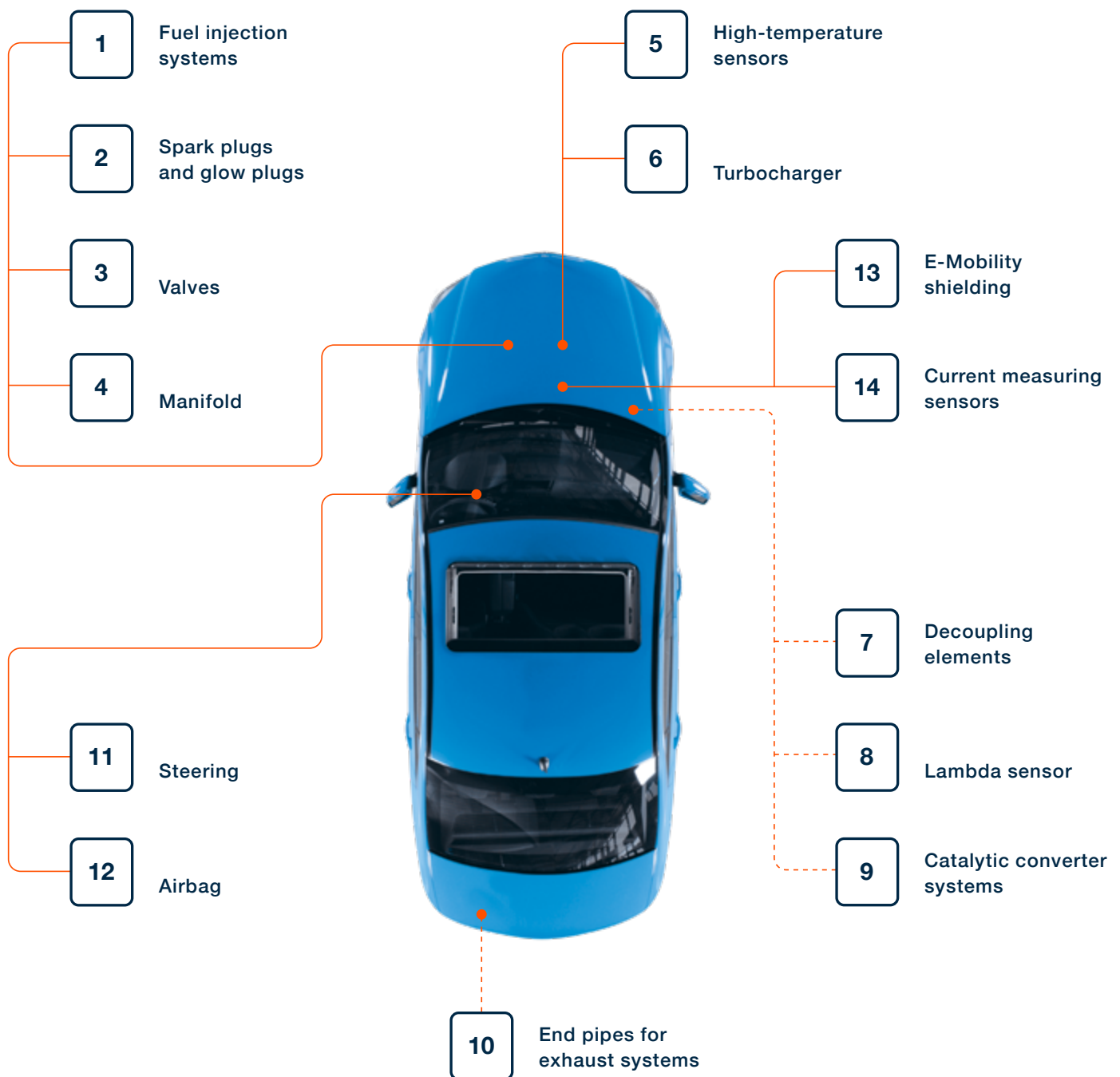
The trend is towards ever more electronic components or electric drives in order to save resources and protect the environment. The electronic parts and components entail different challenges than components in conventional engines. The increasing degree of electronics in automobiles leads to coupling and interference fields that need to be avoided. Here too VDM Metals has recourse to materials for pioneering technologies that have proven effective in other industries. Hybrid and electric vehicles call for materials that can counter magnetic interference fields. VDM® MAG 50 and VDM® MAG 7904 are used in shielding at this point.

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Current measuring sensors

These sensors measure the amperage inductively in lines, in other words without contact. Materials used frequently here are VDM® MAG 50 and VDM® MAG 7904.

... for various applications



Alloys and applications

Corrosion resistant alloys

VDM Metals designation	UNS	DIN EN	Typical chemical composition, in %	Application	Product form				
					Strip	Wire	Bar	Billet	Plate
VDM® Alloy 31	N08031	1.4562	Fe-31Ni-27Cr-6.5Mo-1.2Cu	End pipes for exhaust systems	•	•	•	•	•
VDM® Alloy 625	N06625	2.4856	Ni-21.5Cr-9Mo-4.5Fe-3.5Nb	Decoupling elements	•	•	•	•	•
VDM® Alloy 926	N08926	1.4529	Fe-25Ni-20.5Cr-6.5Mo-0.9Cu-0.2N	Turbocharger, end pipes for exhaust systems	•	•	•	•	•

High-temperature alloys

VDM Metals designation	UNS	DIN EN	Typical chemical composition, in %	Application	Product form				
					Strip	Wire	Bar	Billet	Plate
VDM® Alloy 40 B	–	1.4888	Fe-37.5Ni-21Cr-1.6Si-0.1La	Manifold, glow plugs, turbocharger, protective tube lambda sensor, high-temperature sensors	(•)	•			
VDM® Alloy 310 S	S31008	1.4845	Fe-25Cr-20Ni-0.5Si	Turbocharger	•				
VDM® Alloy 314 L	S31400	1.4841	Fe-25Cr-20Ni-2Si	Turbocharger	•				
VDM® Alloy 600	N06600	2.4816	Ni-16Cr-9Fe-0.07C	Lambda sensor, airbag	•		•	•	•
VDM® Alloy 600 H*	N06600	2.4816	Ni-16Cr-9Fe-0.07C	High-temperature sensors, lambda sensor	(•)		•	•	•
VDM® Alloy 601	N06601	2.4851	Ni-23Cr-14Fe-1.4Al	Glow plugs, manifold, turbocharger, protective tube Lambda sensor, high-temperature sensors	•	•	•	•	•
VDM Alloy 602 CA®	N06025	2.4633	Ni-25Cr-10Fe-2.2Al-0.17C-0.1Y-0.1Zr	Glow plugs	•	•	•	•	•
VDM® Alloy 602 MCA	–	2.4833	Ni-25Cr-10Fe-2.3Al-0.1Y-0.1Zr-0.07C	Manifold, high-temperature sensors, protective tube lambda sensor	•		(•)		
VDM® Alloy 625	N06625	2.4856	Ni-21.5Cr-9Mo-4.5Fe-3.5Nb	Airbag, contact springs lambda sensor, decoupling elements	•	•	•	•	•
VDM® Alloy 800 H	N08810	1.4876, 1.4958	Fe-30.5Ni-20.5Cr-max.0.7Al+Ti	Manifold, turbocharger	•		•	•	•

* solution annealed condition

Superalloys

VDM Metals designation	UNS	DIN EN	Typical chemical composition, in %	Application	Product form				
					Strip	Wire	Bar	Billet	Plate
VDM® Alloy 80 A	N07080	2.4952	Ni-20Cr-2.3Ti-1.4Al	Valves		(•)	•	•	
VDM® Alloy 718	N07718	2.4668	Ni-19Cr-17Fe-3Mo-5.3Nb-1Ti-0.5Al	Turbocharger, contact springs lambda sensor	(•)	•	•	•	(•)
VDM® Alloy 751	N07751	2.4694	Ni-16Cr-7Fe-2.3Ti-1.2Al-0.95Nb	Valves			•		
VDM® Alloy A-286	S66286	1.4980	Fe-25.5Ni-15Cr-2.1Ti	Turbocharger, contact springs lambda sensor	•				
VDM® Alloy C-263	N07263	2.4650	Ni-20Co-20Cr-5.8Mo-2.2Ti-0.5Al	Turbocharger	•	(•)	(•)	•	•
VDM Alloy 788 A®	–	2.4959	Ni-20Cr-12Fe-5Co- 2.5Ti-1.6Al-0.17Si	Valves			•		

Special alloys

VDM Metals designation	UNS	DIN EN	Typical chemical composition, in %	Application	Product form				
					Strip	Wire	Bar	Billet	Plate
VDM® Aluchrom 4 18 Y HF	–	1.4737	Fe-18Cr-4.3Al-0.05Y-0.05Hf	Catalytic converter systems	•				
VDM® Aluchrom Y Hf	K92500	1.4767	Fe-20Cr-6Al-0.05Y-0.05Hf	Catalytic converter systems	•				

Controlled expansion alloys

VDM Metals designation	UNS	DIN EN	Typical chemical composition, in %	Application	Product form				
					Strip	Wire	Bar	Billet	Plate
VDM® Alloy 36	K93603, K93600	1.3912	Fe-36Ni	Fuel injection systems	•	•	•	•	•

Soft magnetic alloys

VDM Metals designation	UNS	DIN EN	Typical chemical composition, in %	Application	Product form				
					Strip	Wire	Bar	Billet	Plate
VDM® MAG 50	K94840	1.3922, 1.3927	Fe-48Ni	E-Mobility shielding, steering torque sensors, current measuring sensors	•	•			
VDM® MAG 7904	N14080	2.4545	Ni-14Fe-5Mo	E-Mobility shielding, steering torque sensors	•	(•)			•

Spark plug alloys

VDM Metals designation	UNS	DIN EN	Typical chemical composition, in %	Application	Product form				
					Strip	Wire	Bar	Billet	Plate
VDM® Alloy 600 L	–	2.4817	Ni-15Cr-7Fe-max.0.025C	Spark plugs	•	•			
NiCr2Mn	–	2.4145	Ni-2Cr-2-Mn	Spark plugs		•			
NiCr2MnSi	–	2.4146	Ni-2Cr-1.5Mn-0.5Si	Spark plugs		•			
NiCr5MnSi	–	2.4151	Ni-5Cr-2.8Mn-1.8Si	Spark plugs		•			
NiMn4Si	–	2.4190	Ni-4Mn-1Si	Spark plugs		•			
NiSiAlY Hf	–	2.4133	Ni-1.6Si-1.3Al-0.08Hf	Spark plugs		•			

Integrated production

Projects and production in the automotive industry are characterized by high standards in terms of product safety, reliability and longevity, requiring partners with know-how and expertise. VDM Metals has more than 80 years of experience in designing and producing materials of the highest quality standards. The company operates production sites in Germany and the United States, covering the majority of important production steps – from melting to hot forming to cold forming.

Melting and casting

VDM Metals' nickel alloys and special stainless steels are melted in an electric arc furnace or an induction furnace and then subjected to vacuum treatment. A ladle furnace is available for secondary metallurgical treatment. Casting takes place in a vertical continuous caster or by ingot casting. In addition to the conventional technology of open melting, VDM Metals uses the technology of vacuum induction melting (VIM). The homogeneity and purity of our materials can be enhanced by electroslag (ESR) or vacuum arc remelting (VAR). The ingots serve VDM Metals as starting material for the production of sheets and plates, strips, forgings, bars and rods, wire and welding consumables.

Strip

Strip is cold rolled on four-high and Sendzimir mills. Foil can be rolled down to a thickness of 0.001 in (0.025 mm) on a special 20-high mill. Annealing, levelling and cutting equipment is available for finishing operations to meet customer specifications.

Wire and welding consumables

VDM Metals produces wire in fine and ultra-fine gauges down to a diameter of 0.004 in (0.1 mm), heavy gauge and section wire as well as welding wire.

Rods and bars

For the production of forged bars with a diameter of more than 4.72 in (120 mm) and semi-finished products, state-of-the-art turning lathes, peeling and grinding machines are available.



The production of hot-rolled and forged bars with a diameter of less than 4.72 in (120 mm) is performed with modern peeling and grinding machines. A 60-ton drawing bench is available for the manufacture of cold-drawn precision bars. Length and diameter of our rods and bars vary, depending on material and production process – in general, diameters up to 12.8 in (325 mm) and lengths up to 472 in (12 m) can be produced. Alternatively, the hot rolling of round bars, flat bars, and specialty shapes is performed on either a 14 in (355 mm) or a 10 in (254 mm) hand mill. VDM Metals' finishing plants are equipped with heat treatment furnaces, pickling, shot blasting and cutting units.

Sheet and plate

Sheet and plate in thicknesses of 0.12 to 3.93 in (3 to 100 mm) are hot rolled on a four-high mill, before finishing steps

such as annealing, grinding, shot blasting, pickling and cutting take place. VDM Metals operates a Sendzimir reversing mill that can process hot-rolled sheet to cold-rolled sheet in widths of up to 98.42 in (2,500 mm) and thickness down to 0.04 in (1 mm).

Forgings

VDM Metals' 45 MN forging press uses two manipulators and receives its feedstock from dedicated heating and reheating furnaces. Following precisely specified procedures, bars, billets and other semi-finished products are produced.



Comprehensive Customer Support

Customer relationships with VDM Metals mean access to a variety of first class services – services that really make the difference.

Technical customer support

From selecting the right materials to any request on specifications, properties and fabrication characteristics – VDM's Application Engineering team will be more than happy to provide you with prompt answers and support, relying on their technical and metallurgical background and experience in all fabrication matters of VDM's materials.

Material and corrosion tests

Quality is a top priority at VDM Metals. In addition to the approvals for individual plants, all quality management systems of the different VDM Metals locations are certified according to ISO 9001 and AS 9100. Extensive product tests and examinations are carried out in our on-site laboratories. This includes our metallography, our spectral laboratory, our chemical laboratory, our corrosion laboratory or our mechanical laboratory.

Research and Development (R&D)

The performance of our materials depends decisively on their chemical composition. This may be surprisingly simple or highly complex, but in every case it is the result of intensive R&D work. Our aim is not just to develop new materials but also to sound out hidden performance potentials in market-proven alloys which we can then qualify for new applications. Our R&D experts accompany the projects, sometimes right up to commissioning and start-up. The solutions that evolve find their way into new products, as well as techniques and processes.

Individual solutions for logistic requirements

VDM Metals offers individual solutions for the special demands of the worldwide automotive industry. Together with our customers we develop solutions for their specific needs. By this we are able to meet the different requirements regarding just-in-time production, reliability and delivery times.

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